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Influences of deep learning, need for cognition and preparation time on open- and closed-book test performance

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OBJECTIVES The ability to master discipline-specific knowledge is one of the competencies medical students must acquire. In this context, 'mastering' means being able to recall and apply knowledge. A way to assess this competency is to use both open- and closed-book tests. Student performance on both tests can be influenced by the way the student processes information. Deep information processing is expected to influence performance positively. The personal preferences of students in relation to how they process information in general (i.e. their level of need for cognition) may also be of importance. In this study, we examined the inter-relatedness of deep learning, need for cognition and preparation time, and scores on open- and closed-book tests.

METHODS This study was conducted at the University Medical Centre Groningen. Participants were Year 2 students (n = 423). They were asked to complete a questionnaire on deep information processing, a scale for need for cognition on a questionnaire on intellectualism and, additionally, to write down the time they spent on test preparation. We related these measures to the students' scores on two tests, both consisting of open- and closed-book components and used structural equation modelling to analyse the data.

RESULTS Both questionnaires were completed by 239 students (57%). The results showed that need for cognition positively influenced both open- and closed-book test scores (β-coefficients 0.05 and 0.11, respectively). Furthermore, study outcomes measured by open-book tests predicted closed-book test results better than the other way around (β-coefficients 0.72 and 0.11, respectively).

CONCLUSIONS Students with a high need for cognition performed better on open- as well as closed-book tests. Deep learning did not influence their performance. Adding open-book tests to the regularly used closed-book tests seems to improve the recall of knowledge that has to be known by heart. Need for cognition may provide a valuable addition to existing theories on learning.

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INTRODUCTION

The ability to master discipline-specific knowledge is one of the competencies medical students must acquire. In this context, 'mastering' means being able to recall and apply knowledge. A way to assess this competency is to use open-book tests (focusing on knowledge application), alongside closed-book tests (focusing on recall and application of basic knowledge).[1] Using different test formats can influence student learning behaviours.[2,3] Open-book tests were expected to stimulate the use of the academically preferred deep learning approach.[4] However, a recent study revealed that students used a deeper learning approach in preparation for a closed-book test than in preparation for an open-book test.[5] The authors discussed whether other ways of information processing and other variables might affect study success. From a psychological point of view, need for cognition, reflecting the degree to which an individual chooses to engage in cognitive activities and information processing, may play an important role.[6,7] Therefore, this study focuses on the relationships between the concepts of deep learning and need for cognition, and open- and closed-book test results.

Deep learning and need for cognition

Individuals differ in the way they process information. A person's approach to information processing can be influenced by the situation or task to be performed, as well as by individual differences.[7,8] Educationalists and educational researchers often consider learning approaches in terms of the way a student responds to a learning task in a given context.[6] A learning approach concerns both the student's intentions and his or her personal views on a particular learning task.[9] Since the early 1980s, descriptions of student learning approaches have shown a growing consensus.[10] Two qualitatively different approaches to learning, deep and surface learning, have been consistently identified and are regarded as established concepts today.[10–13] The kind of learning approach a student adopts depends on his or her *perceptions* of the learning task.[8] Students with a surface approach focus on rote learning with the intention of becoming able to reproduce the learning material.[11–13] Students applying a deep learning approach try to understand the material thoroughly. To achieve this understanding, students consult several sources, ask questions about the learning material, separate main issues from side issues and reflect on the material they have read.[13–15] The deep learning approach is considered to be most preferable for medical students.[16,17] However, studies of the relationship between deep learning and study success reveal conflicting results.[13,17] It is possible that students' personal preference in terms of how they process information in general (i.e. their level of need for cognition) also plays an important role.[6,7] These preferences are not limited to information processing in an academic context, but include general information processing.

'Need for cognition' refers to the tendency of an individual to engage in effortful cognitive activities and to enjoy thinking.[6,7] It can be represented on a bipolar continuum that ranges from low to high. Need for cognition is less influenced by task and context than by learning approaches, and is partly related to IQ level and personality.[7,18] It reflects a stable, although not invariant, intrinsic drive that can be developed and changed over time.[7] Individuals with a high need for cognition are likely to seek, acquire and reflect on information proactively in order to make sense of stimuli and events.[19] They are also more likely to be curious and to desire new experiences that stimulate thinking.[20,21] Individuals with a low need for cognition usually rely on others to determine the meaning of information and situations. They are less interested in effortful cognitive activities.[7]

Although deep learning and need for cognition are inter-related, they are distinct constructs.[6] Both concepts are associated with the higher-order factor of self-regulation, a category of intellectual behaviour described by Schoenfeld, which is important for medical students.[18,22]

Deep learning, need for cognition, preparation time and performance: the hypotheses

In this study, we concentrated on investigating the relationships between the concepts of deep learning, need for cognition, and preparation time and test results on open- and closed-book tests.

Because students who use a deeper learning approach intend to understand the learning material thoroughly, we might expect them to gain higher test results. This has been found to occur across a range of closed-book assessment methods.[23] In our study, we concentrated not only on knowledge recall and closed-book tests, but also on students' skills in finding and applying knowledge during open-book tests. In such a context, deep learning should also positively influence test results. Consequently, we formulated our first hypothesis: that deep learning positively influences both open- and closed-book test scores.

From a psychological perspective, not only learning approaches in the academic context, but also students' personal preferences for information processing – need for cognition – play an important role.[6,7] Previous studies showed that students with a high level of need for cognition were better able to recall information and comprehend material that required cognitive effort than students with low need for cognition,[7,19] particularly when learning materials were relevant for the task or when the students were confronted with unexpected information or situations.[19] This indicates that students with a high need for cognition are more likely to engage in the difficult cognitive activities needed to resolve inconsistencies in information. Open-book tests and, to an extent, closed-book tests require complex cognitive activities and the ability to deal with and apply an amount of knowledge. Consequently, our second hypothesis assumed that the level of need for cognition would positively influence both open- and closed-book test scores.

Not only student learning approaches, but also the amount of time students spend on learning activities influences test results and performance.[24,25] Consequently, we included preparation time in our study. Students who spend more time on test preparation were expected to use deeper learning approaches and, consequently, to perform better on the tests. Therefore, our third hypothesis assumed that preparation time would positively influence both open- and closed-book test scores.

In a previous study, we showed that there was no difference in difficulty between open- and closed-book tests and that the scores on both tests were positively related.[1] However, the direction of this relationship is as yet unknown: it is unclear which test outcomes predict outcomes on the other test better. Therefore, we also included the relationship between open- and closed-book test scores in this study.

METHODS

Context

This study was performed at the University of Groningen. In the competence-based Bachelor's programme of the medical curriculum at Groningen, knowledge is divided into *core knowledge* and *back-up knowledge*.[1] Core knowledge is the knowledge that every medical professional should know and be able to recall immediately; it is assessed in closed-book tests. Back-up knowledge is defined as knowledge that students need to understand and use properly with the help of reference sources if so desired; it is assessed in open-book tests. Each knowledge test consists of a closed-book and an open-book section. Teachers and experts decide which knowledge is core knowledge and which is back-up knowledge.

Participants and procedure

The participants in this study were Year 2 medical students (n = 423), who were familiar with examinations containing both closed- and open-book questions. The students were informed about the research study, although the hypotheses to be tested in the study were not mentioned.

Before the test, students were asked to complete a questionnaire on deep information processing. Later that study year, students were asked to complete a scale on need for cognition on a questionnaire on intellectualism. This research study was developed with the help and approval of the Faculty Board of Examiners. The students were informed about the study, participation was voluntary and anonymity was guaranteed. We were satisfied that no plausible harm to participants could arise from the study.

Instruments

We used validated questionnaires to measure the students' levels of deep learning and need for cognition and we also gathered open- and closed-book test results.

Deep information processing

To measure the level of deep learning, we used a questionnaire validated in the Netherlands, the Test for Deep Information Processing (DIP).[15] The Test for DIP consists of 24 items. Students completed two equivalent versions of this questionnaire, one with respect to their preparation for the open-book test and one with respect to their preparation for the closed-book test. The items were tailored to the assessment format (DIP closed-book and DIP open-book). The items were divided into three scales: 'Critical reading' (nine items); 'Broaden one's context' (eight items), and 'Structuring' (seven items). Examples of items are: 'When I read a text while preparing for this open/closed-book examination, I quickly distinguish facts from side issues' (critical reading); 'When I read a text while preparing for this open/closed-book examination, I compare what I read with things I already know' (broaden one's context), and 'When I read a text while preparing for this open/closed-book examination, I make notes of

the most important issues' (structuring). All items are scored on a 5-point Likert scale (1 = never, 5 = always). An extra question ('How many hours a week did you spend on average when preparing for this open/closed-book test?') was added to the questionnaire to measure preparation time.

Need for cognition

To measure the level of need for cognition, we used the Need for Cognition Scale on a questionnaire for intellectualism (Intell'95). The Intell'95 is based on work by Cacioppo *et al.* and Ackerman and Goff, and validated in the Netherlands.[18,19,26] The Need for Cognition Scale contains 10 items to be scored on a 5-point Likert scale (1 = does not apply to me, 5 = applies to me very well). The items on this scale measure the individual's desire to deal with or enjoy cognitive activities. Examples are: 'I like situations in which I have to think a lot' and 'I like abstract thinking'.

Open- and closed-book tests

All examinations concerned the theory delivered in a 10-week module. Each module was examined in three consecutive sessions. This study concerned only the outcomes of the first examination sessions of the modules included; thus the examinations concentrated only on the theory delivered in the first 4 weeks of a module. We combined the results of two consecutive modules within the same cohort of students. For each student a total score for the open-book and a total score for the closed-book test were calculated. The entire set of items consisted of 30 open-book and 70 closed-book questions.

Both the open- and the closed-book sections used a multiple-choice question format. The number of alternative answers per item varied from two to four. The items were constructed by expert teachers and edited by specialists in test item construction. Questions were formulated on different levels of understanding, although items that assessed only the recall of facts were not allowed in the open-book sections.

The resources permitted for consultation during the open-book sections were restricted to the literature supplied. Answer sheets were collected after the closed-book questions had been answered and students were then allowed to use their references to complete the open-book test. In a previous study, the reliability and difficulty of open- and closed-book tests were examined using generalisability theory. Reliability varied between 0.71 and 0.85.[2] The open-book test reliabilities were slightly lower than the closed-book test reliabilities, but were still sufficient. The level of difficulty, defined as an average percentage of correct answers, did not differ between these two types of test.

Statistics

We used the structural equation modelling (SEM) program LISREL[27] to analyse the data. Structural equation modelling is a statistical technique which enables path analyses in which the influence of several variables on the two test scores (open-book and closed-book) can be tested simultaneously. This technique takes reciprocal relationships between latent and manifest variables and measurement error associated with these factors into account. This method is more powerful than a multiple regression analysis. The analysis started with the calculation of the total model, using the open- and closed-book test scores as dependent variables. Need for cognition, deep learning for the open-book test, deep learning for the closed-book test, preparation time for the open-book test and preparation time for the closed-book test were included in the model as independent variables. For each relationship a β-coefficient was calculated to indicate how one variable influenced the other. A stepwise backward method was used to simplify the model until it contained only significant relationships. Firstly, all relationships with a t-value < 0.50 were removed from the model. Secondly, after each calculation the relationship with the lowest t-value was removed until the final model, containing only significant relationships, was reached.

To indicate whether a model represented an improvement on the starting model, we referred to differences in chi-squared statistics. Whether a chi-squared value is large or small depends on the degrees of freedom (d.f.). A large chi-squared value in relation to the d.f. corresponds to a bad fit to the data and a small chi-squared value in relation to the d.f. corresponds to a good fit. A large drop in the chi-squared value compared with the difference in d.f. indicates that the changes made in the model represent real improvement.[28]

RESULTS

Both questionnaires were completed by 239 students (57%), of whom 55 were men (23%), 179 women (75%) and five did not indicate their gender (2%). Their mean age was 20.2 years (range 18–31 years).

These gender and age distributions were comparable with those of the total student population. Furthermore, open- and closed-book test scores did not differ between respondents and non-respondents.

To meet the requirements of the LISREL program in terms of numbers of respondents, we replaced missing values (< 1% of the data). With respect to the question about preparation time, we replaced the missing value with the mean score for the total population. With respect to the Test for DIP and the Need for Cognition Scale, we replaced missing values only if the respondent had not omitted more than two items, in which case we replaced the missing value with the respondent's mean score on the subscale in which the value was missing.

The reliabilities of the questionnaires were $\alpha = 0.84$ for the DIP closed-book test, $\alpha = 0.83$ for the DIP open-book test and $\alpha = 0.81$ for the Intell'95. Table 1 shows the descriptive statistics for each variable.

The mean scores on the Test for DIP were comparable with the mean scores of other university students.[15]

Table 2 displays the zero order correlations for all variables. The table shows that both open- and closed-book test scores were positively related to need for cognition. Deep learning was related to open-book scores, but not to closed-book scores. These relationships were further explored using LISREL.

The one-way pathway from closed-book test scores to open-book test scores resulted in a significant β-coefficient of 0.11. However, the one-way pathway from open-book test scores to closed-book test scores was shown to be much stronger, with a significant β-coefficient of 0.72.

Stepwise deletion of the non-significant relationships in the starting model (Fig. 1) resulted in a final model that included only significant relationships (Fig. 2). The chi-squared value and d.f. changed from $\chi^2 = 0.00$, d.f. = 0 (starting model) to $\chi^2 = 5.63$, d.f. = 8 (final model). As this adjustment improved the model significantly, the final model appeared to be the most parsimonious way to represent our data adequately.

DISCUSSION AND CONCLUSIONS

This study showed that need for cognition positively influenced open- and closed-book test scores, and that neither deep learning nor preparation time influenced the scores on either type of test. Furthermore, the results indicated that the ability to deal with and apply knowledge as measured by the open-book tests predicted the ability to recall and apply knowledge as measured by the closed-book tests better than the other way around.

Only the hypothesis that need for cognition positively influences both open- and closed-book test scores was confirmed. This is in line with the results of studies on closed-book tests.[7,19] Proactively seeking, acquiring and reflecting on information also appears to be helpful when students are required to deal with an amount of knowledge during open-book examinations.

This outcome indicates that stimulating need for cognition in students is important to the development

Table 1 Mean, standard deviation and median per variable

	Score*		Deep learning		Preparation time, hours/week		
	OB	CB	OB	CB	OB	CB	Need for cognition
Total (*n* = 239)							
Mean	0.3	0.4	77.5	79.4	11.2.	20.1	37.1
SD	0.5	0.6	10.8	10.9	13.0	17.1	5.6
Median	0.3	0.4	78.0	80.0	10.0	15.0	37.0

* Proportion of correct answers
OB = open-book test; CB = closed-book test; SD = standard deviation

Table 2 Zero-order correlations

		Score		Deep learning		Preparation time		
		OB	CB	OB	CB	OB	CB	Need for cognition
Score	OB	1	0.30*	0.14†	0.15†	0.00	− 0.01	0.19*
	CB		1	0.03	0.06	0.05	0.07	0.20*
Deep learning	OB			1	0.76*	0.17*	0.18*	0.24*
	CB				1	0.10	0.17†	0.30*
Preparation time	OB					1	0.66*	− 0.03
	CB						1	0.02
Need for cognition								1

* $p < 0.01$; † $p < 0.05$
OB = open-book test; CB = closed-book test

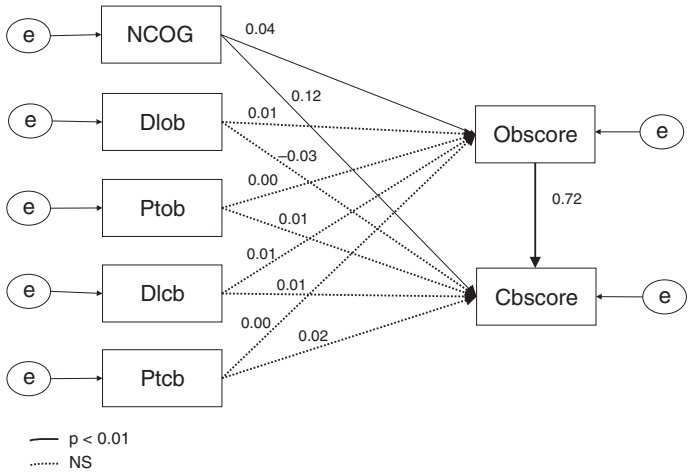

Figure 1 Starting model. NCOG = need for cognition; DLob = deep learning in preparation for the open-book section; PTob = preparation time for the open-book section; DLcb = deep learning in preparation for the closed-book section; PTcb = preparation time for the closed-book section; OBscore = open-book test score; CBscore = closed-book test score

of this characteristic. Previous studies showed that it is possible to develop need for cognition by confronting individuals with situations that appeal for this form of inquiry.[21] In these situations individuals are confronted with complex problems. Such problems are non-routine, do not have well-defined solutions and contain many dimensions that are often interlinked. Thus, confronting medical students with complex problems during their medical training might help them to develop their need for cognition. Further research should focus on the role of need for cognition in academic settings.

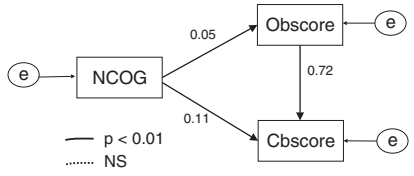

Figure 2 Final model. NCOG = need for cognition; OBscore = open-book test score; CBscore = closed-book test score

One of our most striking outcomes refers to the finding that deep learning influences neither open- nor closed-book test results. A possible explanation could be that need for cognition is a necessary condition for deep learning. It may be the underlying factor and, therefore, the variable that predicts performance. This indicates that theoretical frame-

works that concentrate only on learning approaches and performance may not be optimal. Previous research suggests that need for cognition is predictive of the manner in which people deal with tasks and information.[7,29] Some theories might be extended to include need for cognition as a precursor for deep learning. The restricted number of respondents in the present study did not allow us to test the model in which need for cognition is the mediating variable in the relationship between deep learning and test score. Future research should concentrate on such a model.

A second explanation for not finding a relationship between deep learning and, particularly, open-book test scores may relate to the time available to answer all open-book questions. Students received additional test time because of their participation in this study. It is possible that students who did not use or hardly used a deep learning approach when preparing for open-book tests, used the extra time to look up more information during these tests. In this way they compensated for their more surface preparation. Further research should focus on the influence of restricting test time on students' open-book test scores.

The hypothesis that preparation time positively influences open- and closed-book test scores was also not confirmed. Spending more time on test preparation is related to deep learning and motivation, as indicated in the Introduction.[25] Both deep learning and motivation are expected to influence test scores positively.[17,30] We did not find an influence of deep learning on test scores. However, spending more time on test preparation may also reflect inefficient learning behaviours, which negatively influence test scores.[24,30] It is probable that the positive influence of more preparation time inspired by a higher level of motivation was counterbalanced by the negative influence of increased preparation time resulting from inefficient learning behaviours.

Finally, our study revealed that when students were able to trace and apply knowledge during the open-book tests, they were also better able to recall and apply knowledge during the closed-book tests. Enhanced ability to find and apply knowledge indicated a broader view of the learning content, which might result in a better way of structuring information. Students who were better able to deal with the total amount of knowledge probably made more connections between different areas of information and constructed more comprehensive mental schemas. Such schemas are helpful when students are required to recall and use this knowledge during closed-book tests.[31] These findings indicate that introducing open-book tests not only helps students to handle a large amount of knowledge, but also seems to improve their retention of core knowledge.

A strength of this study is that its participants were drawn from a large cohort of students who were familiar with open- and closed-book test preparation. These students had experienced both types of test format over the course of at least one study year. Furthermore, we asked the students specifically how they had prepared for the tests in our study. Consequently, the answers on the Test for DIP and the test scores are directly linked.

Possible limitations of this study refer to its response rate of 57% and the fact that two-thirds of participants were women, which may have influenced the results. However, as participants did not differ from non-participants in terms of age, gender and test performance, we can conclude that they represented the total student population adequately. Replication of this study is needed to establish the generalisability of our results to other populations.

In conclusion, we found that need for cognition positively influenced test scores on open- as well as closed-book tests, whereas deep learning did not. These results indicate that need for cognition may represent a valuable extension to existing theories on learning.

Contributors: MH-P contributed to the study conception and design, and data collection, analysis and interpretation. She also drafted the manuscript and revised it in concordance with suggestions from the other authors. JBMK contributed to the study conception and design, and data collection and interpretation, and commented on several drafts of the manuscript. WHAH contributed to the study conception and design, and data analysis and interpretation, and commented on several drafts of the manuscript. JC-S contributed to the study conception and design, and data interpretation, and commented on several drafts of the manuscript. All authors approved the final version of the article.

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